TABLE 12.—*Monthly extremes of rainfall, Tela, 1914–1926, inclusive*

[Inches]

Month	Average	Maximum	Minimum	Number of years above or below average	
				Above	Below
January	8.46	21.57	3.21	7	6
February	6.38	16.25	1.76	5	8
March	5.47	13.66	.26	5	8
April	2.81	6.52	.23	7	6
May	2.73	8.45	.50	7	6
June	5.95	11.03	.66	5	8
July	5.86	9.71	2.60	6	7
August	7.82	13.38	3.85	6	7
September	8.81	20.78	5.27	5	8
October	11.32	26.61	6.40	5	8
November	16.71	33.47	5.88	7	6
December	12.29	29.26	4.35	4	9
Annual	99.68	124.92	52.21	6	7

SUMMARY OF THE CAUSES OF RAINFALL ON THE CARIBBEAN COASTAL PLAIN OF HONDURAS

The location of Honduras in what may be termed the border zone of the equatorial belt is largely responsible for the complexity of climatic conditions found there.

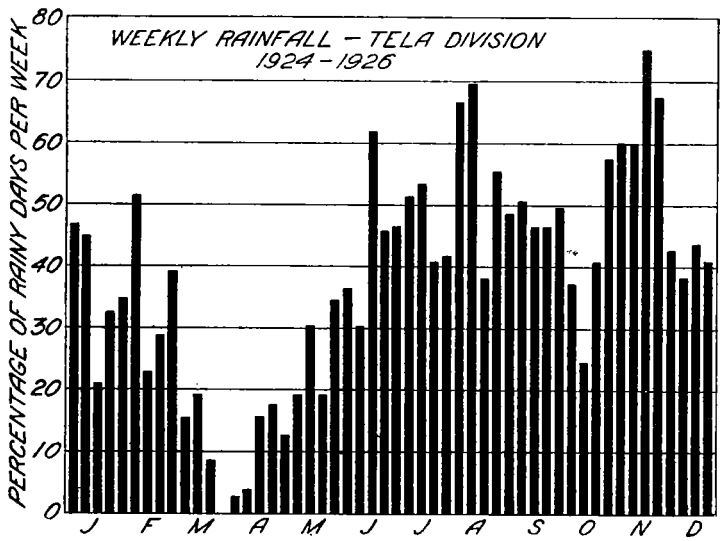

FIGURE 4.—Weekly rainfall—Tela division, 1924–1926

Seasonal variations occur, of course, with the north and south migration of the climatic belts, but variability is caused also by irregular penetration of equatorial and temperate weather conditions beyond their customary limits at various seasons. Thus at times in the winter months *northers* induced by pressure conditions in the central interior of North America sweep across the Gulf of Mexico and into the Caribbean borderlands, especially the north coast of Honduras, and give days of chilly, raw, drizzly weather. On the other hand, there are times when opposite conditions are true, and lobes of equatorial low pressure extend into the area even in the winter season. Thus Honduras, though dominated by the northeast trades, also is periodically affected by the equatorial calms, to a lesser extent by the extratropical high-pressure belt, and occasionally even feels the effect of the cyclones of the northern westerlies.

The basic causes of the rainfall on the Caribbean coastal plain of Honduras therefore appear to be:

1. The equatorial rain belt which extends across and beyond Honduras during the summer, the heavy rains lagging some weeks behind the vertical sun. This in large measure accounts for the heavy summer rainfall period.
2. The northeast trades, which, since leaving the West Indies, have traversed the warm Caribbean, bring the heavy rains of autumn, culminating in November. In that season the waters of the Caribbean are warmest and the receding sun gives rise to cooling of the land, hence maximum precipitation.
3. The "wet northers" which are produced by winds from the north after crossing the warm Gulf of Mexico.
4. Cyclonic storms which develop along border zone of high and low pressures and sometimes attain considerable violence, with resultant heavy rains.

Concomitant with these causes, consideration should also be given the narrowness of the plain, and the slopes of the adjacent border mountains. The relief undoubtedly has an important relation to the development of local convection currents and hence to local rainfall conditions. It is very possible that further study of the details of local relief may furnish the key that will account for some of the dry spots and some of the wet spots which are at present attributed entirely to variability and hence are considered to be purely accidental. There may be a reason in some instances—the story can not yet be finally told.

WEATHER ABNORMALITIES IN THE UNITED STATES

By ALFRED J. HENRY

[Weather Bureau, Washington, D. C.]

The study of weather abnormalities has a very real attraction for many students of the weather map. I consider such studies as among the most promising that can be made especially when the much greater problem of seasonal forecasting is in view. A better understanding of the causes of the irregularities or abnormalities of the weather must form a preferred avenue of approach to the problem of long-range forecasting.

Hitherto the lack of observational data for the more remote places on the globe has been so great as to seriously handicap any organized effort to elucidate the cause or causes of weather abnormalities. While the results of the efforts herein described are negative and the paper must be considered as of an exploratory character, it is printed in the hope that it may induce similar studies for other localities in the years that are to come.

The weather of 1915 in the United States and elsewhere in North America was abnormal in several respects, especially as to the distribution of temperature and precipitation over very considerable areas. From May to September the temperature was unusually low, in fact the mean temperature for the summer months June–August was the second lowest at many stations during the last 50-odd years.

The precipitation in one or more States west of the Mississippi, almost in the center of the continent was unusually heavy with the result that disastrous floods were produced in the streams of the region and a large property loss was entailed. The number of severe hailstorms in the Plains States was unusually large and the destruction of growing crops was very great.

Other exceptional weather phenomena were as follows: Three severe tropical cyclones from the Gulf of Mexico entered the continent and continued a long distance before dissipating, two in August and one in September, and finally two northers occurred in the Canal Zone in April—an event not hitherto recorded since the occupation of that zone.

From the foregoing it is apparent that the normal atmospheric circulation over the North American Continent for a part of the year at least, must have been materially disturbed. Let us first consider the temperature.

The distribution of temperature east of the Rockies is closely related to the prevailing direction of the wind and this in turn is controlled by the paths followed by cyclonic and anticyclonic areas in their movement across the country. When cyclones follow the northern circuit they induce southerly winds and when, as sometimes happens, the cyclones are not closely followed by strong anticyclones warm weather results. Warm weather also prevails in eastern districts, as pointed out by Humphreys, when the western part of the North Atlantic is occupied by mean pressure greater than normal. On the other hand when pressure over the western North Atlantic is low, northerly winds from the interior of the continent will be induced and the temperature in Atlantic coast districts sinks.

In the United States the locus of the greatest depression of temperature in May was over the upper Lake region, in June and July over the upper Missouri Valley, in August it had been shifted to the middle Mississippi Valley, and in September back far to the northwest in northern Montana. Thus it may be inferred that the controls were not the same for each of the months and this view is strengthened by the discovery of the initial cause of the cooling, viz, in the origin and movement of four vigorous anticyclones over or near to the west shore of Hudson Bay as recited in the following excerpt from the Canadian Monthly Weather Review for May, 1915, page 65.

HIGH AREAS.—Seven areas of high pressure were traced. One first appeared over Alberta, *four over or in close proximity to the western shores of Hudson Bay (Italics mine)*, one on the coast of the Middle Pacific States, and one in southern Montana. The four areas from Hudson Bay were quite remarkable for the season of the year. Spreading southward to the Great Lakes, and very energetic, they caused a great preponderance of cold, dry north and northeast winds, as well as frost on several occasions, from Ontario eastward, the latter doing more or less damage locally to vegetation. The system which appeared near Port Nelson on the 25th, reached northern Michigan on the 26th, then receded and lay to the northward of the Great Lakes until the close of the month. It was attended by sharp frosts from Ontario to the Maritime Provinces, an occurrence which seldom happens so late in the season.

It is conceivable that a snow cover in the region about Hudson Bay would tend to facilitate the formation of intense anticyclones. Inquiry addressed to the Canadian Meteorological Service elicits the information that no unusual surface conditions existed in May, 1915. I quote from the letter of Mr. A. J. Connor, climatologist, especially as to the possibility of the bay freezing over in winter:

There is always some traveling during a winter along the shore ice of Hudson Bay, from post to post, by the factors or their people, but beyond this the bay is deserted in the winter. The question of ice in the bay has, however, come up at parliamentary and departmental discussions several times. These discussions have caused searches of the records of the Honourable Company of Gentlemen Adventurers trading into Hudson's Bay since Prince Rupert's first charter, as well as inquiries into other sources of information. The conclusion is that Hudson Bay has never frozen over in historical times. Heavy shore ice forms and ice fields of varying extent float in the bay, but it has been stated that a properly equipped ship could navigate in the bay itself all winter.

The records from Nelson and from Hudson Strait in 1915 make no mention of any unusual occurrence, so that we may assume that ice conditions did not differ (noticeably to our observers at least) from the normal.

The tracks of pressure maxima were charted by Mr. Webber, who was in the service at that time (May 1915), from the data then in hand, but since our radio service was not then in existence he had very little to work upon in the north. Material which we received long after that date by mail indicate that the "four energetic anticyclones" were extensions or tongues of a pressure maximum which persisted all month in the regions of the archipelago. The flow of air on the eastern side of this area during a large part of the month was apparently so arranged that the circulation was from the Ellesmere side of the polar basin south, but also spreading fanwise west over a large part of the continent. The temperatures were not low, the mean for the month in Baffin Land was normal, at Nelson about 2½° below normal.

At Bernard Harbor (70° N.; 115° W.) the pressure rose to about 30.70 inches on some days and above 30.90 inches on the 17th, but the maximum was evidently always east of this point, on most days evidently in the archipelago; though toward the close of the month it would seem that there was a maximum in a more southerly latitude, connecting by a neck of high pressure with another maximum near or beyond the pole.

* * * The general effect during the month was of a moderately cold front of quasi-maritime character from the eastern polar region, flowing fanwise south and west into the interior of the continent. A part of the warm front from the Caribbean area passed west and up the western side of the continent into the circulation from the Pacific. A part of the remainder of the warm front attempted to pass up the center and east of the continent, but was frequently forced to rise in the environment created by the northeast polar front cutting in on both flanks.

In the January, 1929, REVIEW, page 22, mention is made of several cyclonic storms which after reaching the coast of Newfoundland were displaced northwestward into the interior as far as Hudson Bay. The fact that there is open water in the bay in winter is evidence of the existence of a relatively warm column of air over that body of water. This air, due to the existing baric gradients, would be blown to the southeast and over the Canadian Maritime Provinces, and this fact may, in part, explain the abnormal course pursued by the cyclonic storms in question.

The cause of the cool weather in May, 1915, is thus definitely determined; it is not probable that the cool weather of the succeeding three summer months was wholly due to the same initial cause.

Assuming that the primary control of the winds rests in the pressure distribution, I have constructed charts of monthly mean pressure anomaly for the Northern Hemisphere for December, 1914, up to and including July, 1915. The pressure anomalies of this period were rather pronounced in those parts of the globe that are naturally subject to large pressure fluctuations. The charts for January–June, 1915, are shown in reduced size in Figure 1.

Owing to the small number of normal pressure stations in the Northern Hemisphere, 256 for January, there must be some uncertainty in the course of the lines of zero change, especially over the oceans and in the Arctic, where there are no observing stations.

While it is not safe to generalize from a very few charts, nevertheless one or two tendencies may be noted, first, there appears to be a progressive movement from west to east of pronounced pressure abnormalities, although there is no definite rule as yet apparent; second, there is a tendency toward a reversal of sign in the pressure abnormality from one month to the next in any region, and the same rule is more or less applicable to all other meteorological elements. Also it may be remarked that the amplitude of pressure oscillations is much greater in high than in low latitudes and that certain regions of the Northern Hemisphere are particularly susceptible to large pressure oscillations such as areas of great temperature contrast—the Iceland region and northwest Europe,

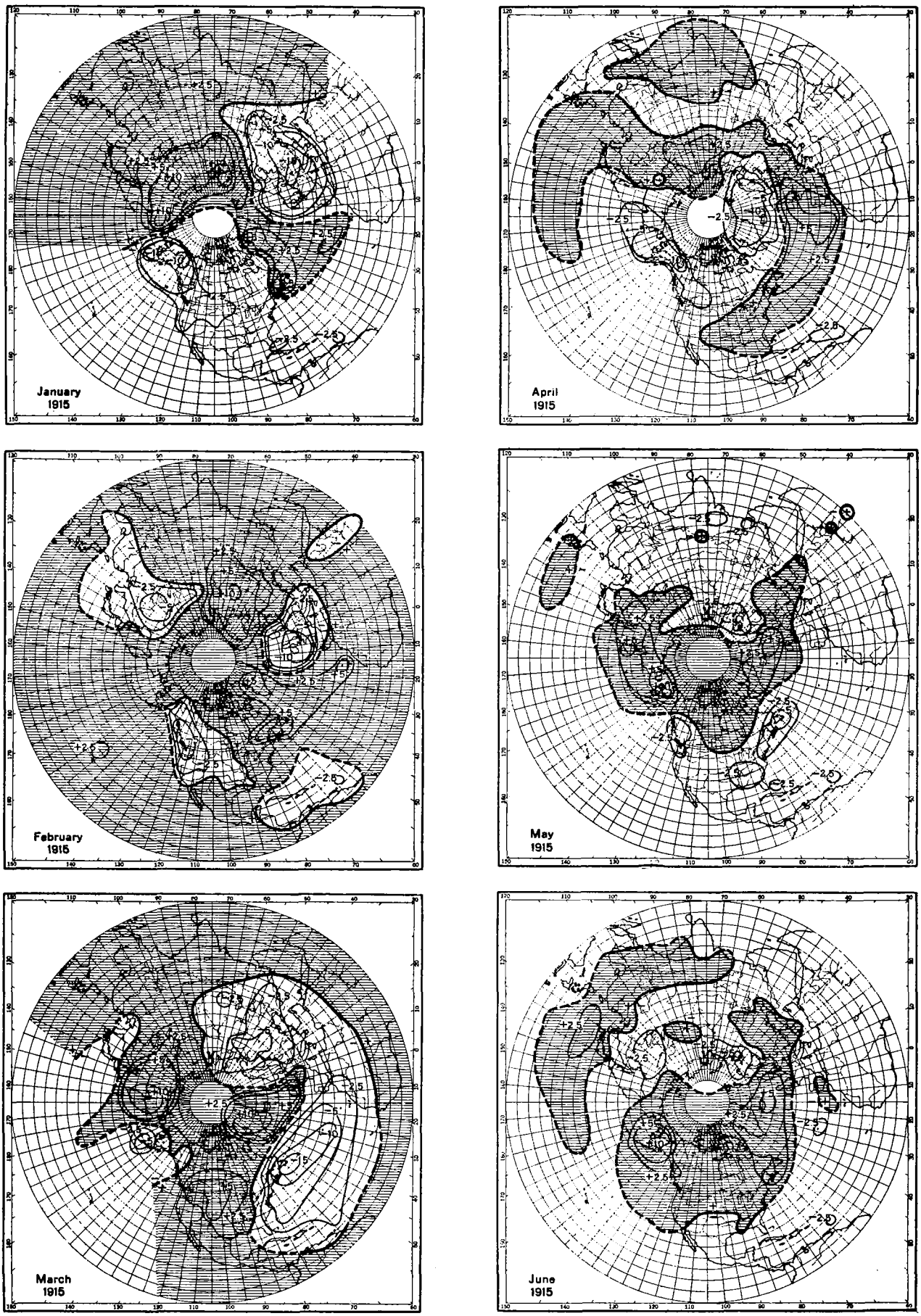

FIGURE 1.—Abnormalities of pressure, Northern Hemisphere, January to June, inclusive, 1915. Positive areas are shaded, negative areas unshaded

for example. The continent of Europe is much more subject to large pressure oscillations that that of North America.

As a rule the charts speak for themselves; I shall discuss very briefly those for March to June, inclusive.

March, 1915, Chart D.—This chart as compared with that of the previous month shows evidence of a progression of the abnormalities from west to east and also of the development of a strong negative isabnormal over the North Atlantic where the previous month showed a moderate positive isabnormal; the greatest negative abnormality was recorded at St. Johns, Newfoundland, 16.1 mb. (0.48 inch). This abnormality stretched across the Atlantic and impinged upon the northwest of Africa. The Siberian negative isabnormal of February apparently advanced to Alaska being replaced by a positive isabnormal of considerable magnitude.

In this month high pressure was the rule in the Arctic, the single exception being in the case of Dutch Harbor which recorded a negative isabnormal of 9 mb. (0.26 inch). The temperature in the United States was mostly below normal, the definit reaching 9° to 12° over the Plains States and Texas, while in Pacific Coast States and the plateau region negative anomalies prevailed. Precipitation was below normal in the great majority of districts.

April, 1915, Chart E.—In this month there is a suggestion of a ridge of high pressure that almost encircles the globe in rather low latitudes being interrupted only over the central and eastern Pacific. On the polar side of this ridge are two negative isabnormals on opposite sides of the globe. A pressure distribution such as this is conducive to warm, dry weather in temperate latitudes.

May, 1915, Chart F.—In this month high pressure in the Arctic save for a sector in northern Europe is the dominating influence. Pressure in the Tropics is prevailingly low, but since the oscillations there are of small amplitude lines of equal abnormality have not been drawn. The opinion is expressed that the positive isabnormal that extends westward from the coast of Norway includes that part of North America above latitude 50° N., a region in which there were very few meteorological stations in May, 1915. Information received from the Canadian Meteorological Service, previously quoted, supports this conclusion, and it may be concluded with much confidence that the abnormal temperature of that month in the United States and Canada was due to the high pressure in the Hudson Bay region as previously indicated.

June, 1915, Chart G.—The outstanding feature of the June and July charts is the high pressure in the polar region, and this is also true, though in less degree, for August of the same year.

FLOODS IN MISSOURI VALLEY, HAIL IN PLAINS STATES

Heavy and continued rains in the lower Missouri Basin in May continuing into June resulted in disastrous floods in that basin entailing a monetary loss of over $6,000,000. The details may be found in this REVIEW for May and June, 1915.

The loss from damaging hail storms in Kansas and adjoining States was exceptionally heavy. The hail fell almost coincidentally with the ripening of the wheat crop, thus causing a very heavy loss.

Both the heavy rains and the large number of hail storms in May and June, 1915, are, in the opinion of the author, directly due to the high pressure in the Hudson Bay region, which retarded the northeastward course of low-pressure areas passing across the Plains States, thus permitting them to precipitate large quantities of rain.

Fortunately further details as to the pressure distribution over Siberia for the winter of 1914–15 are available in the work of Grebojedov[1] who has considered the pressure over that region from November, 1914, to March, 1915, as a whole and also in five subperiods as follows:

(1) *November 1 to 27, 1914.*—A period of positive pressure anomaly over Siberia with two centers of large anomaly, the first over the lower Ob Valley, plus 4 mm., and the second of 6 mm. directly east of Lake Baikal centered at a single station, probably Tchita.

(2) *January 3 to February 4, 1915.*—A second period of very large positive anomaly over Siberia, disposed geographically precisely as the one just described with this difference, the positive anomaly over the lower Ob Valley being 12 mm. and east of Lake Baikal the same; there was also a negative anomaly over the Caspian region of 2 mm., and this region of negative anomaly extended eastward as far as the ninetieth meridian of east longitude.

(3) *February 21 to March 12, 1915.*—A third period of positive pressure anomaly disposed precisely as the two first described but of somewhat less intensity.

(4) *November 28, 1914, to January 2, 1915.*—A period of pronounced negative anomaly over central and northeastern Siberia, the negative anomaly being 10 mm. at about 62° N. and 130° E., diminishing thence southeastward to zero in the latitude of Lake Baikal and changing to a positive anomaly southward.

(5) *February 5 to 20, 1915.*—A second period of pronounced negative anomaly over the same region as just described, the maximum negative anomaly being 12 mm. at the same geographic point as before diminishing thence southward and southwestward and naturally changing to positive anomaly that amounted to 7 mm. in the Caspian Sea region.

Thus he shows that over Siberia and probably a great part of Asia there were five major pressure oscillations between November 1, 1914, and March 3, 1915, and that the sequence was as follows plus-minus-plus-minus-plus. The average duration of each pulsation was 24 days although the last one was but about half that number. It may be concluded that these pulsations or oscillations dominated the weather of the greater part of Asia. The significant feature, however, must be the fact that cyclonic storms or depressions must have been in evidence over the most inhospitable terrain for such storms to be found in any other part of the earth except the very high latitudes. The résumé of International Meteorological Observations issued by the Weather Bureau under the title "Bulletin A, Washington, 1891," clearly shows that the region east of Lake Baikal in Siberia is less frequented by cyclonic storms than any other equal area in the same latitude around the globe. It would seem that such an exceptional phenomenon must be reflected in other parts of the globe. Unfortunately for our purpose, however, there are no means at hand to determine whether the cyclones of northeast Siberia from November 28, 1914, to January 2, 1915, endured long enough to reach North America.

Daily weather charts for the North Pacific would aid greatly, but these are not available and we must have recourse to the weather summaries issued by the Canadian Meteorological Service and the United States Weather Bureau for the North American Continent. These show that the month of December, 1914—a month of low pressure in Siberia—was essentially a month of high pressure in Canada and the United States with temperature considerably below the normal. The anticyclones of Canada, of which there were nine, were for the most part vigorous, widespread, and persistent; they were attended by much cold weather. Pressure in the United States, especially in Alaska was high and temperature

[1] Grebojedov, S. Les cycles périodiques accomplis dans l'activité' de l'anticyclone de Sibérie. Recueil de Géophysique, tome III, fasicule 3, 1916. Publié par L'Observatoire Physique Central Nicolas.

below the normal. The pressure in North America was therefore directly in the opposite sense to that in Siberia. Considering next the second period of low pressure in Siberia, viz:

February 5 to 20, 1915.—A month of unusually low pressure in central and northeast Siberia; while nine anticyclones were charted in Canada, it is said of them that they were not as energetic as is often the case in the winter season and their accompanying cold waves also lacked intensity, the result being a mean temperature in Canada very much above the average. During this month low pressure had overspread northwest Canada and the United States west of the Rockies, and the temperature everywhere in the latter except in Arizona and western New Mexico was considerably above the normal. Precipitatión was abundant on the Pacific coast, the Missouri Valley, and the upper Mississippi Valley. The inference from the foregoing seems to be that the low pressure in Siberia had spread eastward across the Pacific into Alaska and over the western part of the continent as far south as Mexico. On the eastern seaboard, however, the opposite pressure conditions prevailed.

Consider now the three cases of high pressure in Siberia. I remark first that the time intervals of these, viz, November 1 to 27, January 3 to February 4, and February 21 to March 3 do not except in the two cases first mentioned lend themselves to direct comparison with calendar month means.

November 1 to 27, 1914. A month of high pressure in Siberia.—Pressure in Canada and the United States was not far from normal with a tendency toward high pressure in the western part of the continent, except that low pressure was the rule in Alaska and northwest Canada. Nine anticyclones were charted in Canada and 13 in the United States, 5 of the latter coming from Canada. In general they were lacking in intensity and, partly due to that fact and partly to the movement of a large number of cyclones eastward along the border between Canada and the United States, the month as a whole was warm from the Atlantic to the Pacific and as a rule dry.

January, 1915: High pressure in Siberia.—Pressure was half an inch below the average at Dawson, Yukon Territory, and a less amount generally throughout northwest Canada; while 10 anticyclones were charted in that country they were not of the energetic type often prevailing in January. Fourteen cyclones were charted, half of which first appeared on the Alaskan coast or in other words along the eastern margin of the winter anticyclone of Siberia. In United States pressure was low in many parts of the country, the greatest departures being in the lower Missouri Valley, Kansas, northern California and western Oregon, and western Washington. Thirteen anticyclones were charted, eight of which came from Canada and four from the Pacific. The temperature was close to normal in all parts of the country and precipitation was fairly abundant in the majority of districts.

It must be confessed that the pressure level in the region usually occupied by the great winter anticyclone of Siberia does not appear directly to greatly modify or influence the weather in North America either currently or subsequently. Indirectly, however, it may enter as a causative influence, thus when pressure is much above its normal level in Siberia low pressure is likely to be the rule on its eastern margin which in turn makes for mild winter temperature and diminished precipitation in North America; on the other hand when pressure is much depressed in northeast Siberia, the probabilities are that pressure over Alaska and northwest Canada will be high and thus create low temperature and moderate precipitation in North America. The evidence is however incomplete and inconclusive.

NOTES ON LINE SQUALLS

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By C. G. ANDRUS

[Weather Bureau, New York, N. Y.]

Line squalls have earned for themselves a reputation of severity and malevolence which has made airman deal with them with respect and caution. Fatalities and crashes, frequently with open gun, have been traced to line squalls as the direct or contributory cause in a large number of wrecks attributed to weather. Unlike fog, which is more or less quiet it is an active, moving, and transient expression of meteorological violence and it may generally be observed before its onset and occasionally anticipated with great accuracy. Half the battle so far as the airman is concerned is to be prepared for it; to do this it should be recognized both by its indicative characteristics on the weather map and its actual appearance in the air.

To spot the conditions favorable to line squalls on the weather map it requires that we divide the depressions or "lows," and even the troughs between highs into warm and cold sides. The warm side indicated by southerly winds (SE. to SW.) is found on the lower part of the front of the low; behind the low are NW. winds (W. to N.) and comparatively cold air. Occasionally the question arises quite honestly "what occurs where they meet?" They do not meet in the sense of colliding in an impact, but the cold air by virtue of its heavier weight wedges under the warm breezes from the south which are quite ready to rise as a result of their lighter weight. Where this undercutting cold "front" curls up before it the lighter and usually moist warm air, a long line of squalls and low-arching clouds are now formed as sufficient chilling by both contact and raising condenses the water vapor into rolling clouds, which frequently reach well above the ceiling of ordinary airplanes. The lifting action is rather violent and sudden and the resulting condensation into clouds is abrupt and intense, so that the phenomena associated by experienced airmen with such condensation are frequently found highly developed. The thunderstorm, sleet, severe snow, and extraordinary instability and bumpiness may all be present within the squall which is itself moving forward usually at about 15 to 30 miles per hour toward some easterly direction.

Once detected, their line of march may be timed quite accurately, although it is not equally easy to predetermine their violence which is variable and capricious. The "northers" of the Plains States are line squalls and are sometimes entirely of wind, the moisture supply on both sides of the depression being too scanty even for clouds. Nearer the Lake region and along the Gulf and Atlantic coasts they tend to be "wet" as well as windy. Unfortunately adding moisture to the problem tokens more violence produced by heat liberated by the condensation, as well as nullifies visibility and even ceiling for the airmen. Safety lies in getting through the squall cloud as rapidly as possible, at the same time maintaining a sharp lookout for any brightening areas ahead. All this must